Visualizing skin temperature before, during and after exercise for dynamic area telethermometry

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Abstract – **The dynamic behavior of human skin temperature has potential clinical diagnosis values. The method and material for acquiring and implementing thermal data plays an important role for obtaining a confirmed thermographic diagnosis. High resolution, both temperature and spatial, is required in order to see a dramatically different behavior between the data obtained in a group of patients and the one observed in a group of normal subjects.**

In this paper, a specific exercise is designed; we visualize the skin temperature before, during and after the exercise. Over 2000 frames during the period were captured, and the skin temperature of the regions of interest is analyzed statistically. In order to visualize the FFT to yield the relative contributions of its underlying frequency over the series of frames, the average temperature of the region of interest is obtained in order to average out some of the spurious noise. The subareas of interest are detected automatically using region-growing technique.

The results are obtained using an infrared imaging system at a frame rate 30 frames per second.

I. Introduction

In order to use thermography for clinical diagnosis, it is extremely important to try to compare the reaction of the temperature of healthy subjects and patients when some suitable stresses are applied to the healthy subjects and the patients. Despite considerable individual variability in absolute skin temperature in specific regions and the body as a whole, there are many common features in overall patterns for similar groups of subjects [2, 4]. A highly irregular and generally asymmetrical distribution

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Abstract

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Dynamic Area Telethermometry (DAT) that entails acquisition of hundreds of consecutive infrared images followed by quantitative analysis of the modulation of cutaneous temperature and of its spatial homogeneity has been used to study various regulatory systems, as well as for medical diagnosis [1, 3, 6]. As parts of our work on DAT, the technique presented in this paper provided a good platform.

II. Experiments

In our system, an Infra-Red camera is connected to the Imaging card of a personal computer. A series of thermal images are stored in the hard disk of the computer. This allows us to analysis the dynamic behavior of the temperature of the body-surface.

A. Calibration

A blackbody with resolution 0.1 ^{0}C is used to calibrate the infrared camera. The temperatures of the blackbody were controlled at some fixed values, such as 34 ^{0}C to 40 ^{0}C with step 0.1 ^{0}C, the infrared images of the blackbody are stored. The distance between the camera and the blackbody is approximate 80cm, which is nearly same with the distance between the human and the camera in the exercise discussed bellow. The temperature of the lab is 25^{0}C±2^{0}C. The temperature resolution of the system is found to be approximate 0.2 ^{0}C.

B. Material and method to analyze the temperature changes before, during and after-exercise

An exercise is designed in which subjects are lifting a dumbbell with his/her right hand. The subject stands in front of the infrared camera. A series of frames are captured over 1 minute, including 10 seconds before the exercise, 20 seconds during the exercise and 1 minute after the exercise respectively. The rate of the camera is 30 frames/s, hence there are about 3000 consecutive frames are recorded. The changes of the skin temperature (reflected by the temperature of some regions-of-interest in the right arm of the subject) are measured on these frames. The weight of the dumbbell is 3kg. The size of the image is 640 × 480 with a gray-scale resolution of 8-bits per pixel.

The size of the region of interest is set to be 7×7 that allows reasonable precision for the statistics. The average temperature and the standard deviation of these regions, which will be used for further analysis, are computed.

In order to locate the regions of interest automatically, two special markers (pieces of metal that are far cooler than the skin) are adhered to the skin of the subject, see Fig. 1. The markers, consequently the regions of interest, which are at fixed relation with respect to the markers, can be located easily using the region-growing technique due to the high contrast between the markers and skin.

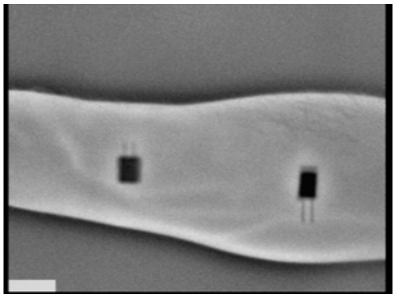
From the series of images, the average temperature of successive five images for a region of interest is considered as the temperature of the region, see Fig. 3. Consequently, a time profile of the average temperature of same spot on each of the images is obtained, and the modulation in that series is analyzed by FFT to yield the relative contributions of its underling frequencies. The average temperature is preferred since it averages out some of the spurious noise. The resolution of the temperature can be improved.

Eight healthy volunteers were examined. The experiments were done in different time of a day, including morning, noon, afternoon, evening, before dinner, after dinner.

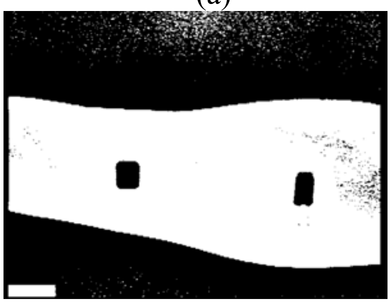
C. Experiment results

As mentioned earlier, the regions of interest are located using the markers. For instance, the location of the ROI of the first frame in a series is shown in Fig. 1. The original image is shown in Fig. 1(a). This image is segmented based on its histogram. The markers become two segmented regions and can be located by applying the region-growing technique to the segmented image, see Fig. 1(b). In the segmented images, two markers should be the two regions having known size and relative positions. The center, represented as C_L and C_R respectively, of the two markers can be located (marked cross, see Fig. 1(c)). The center of the line segment C_LC_R, represented as C, is considered as the center of a ROI. A 7×7 centered C window is taken to be the ROI. More regions of interest are then located with respect to C. E.g. in our experiments, they are positioned on the line that passes through C and perpendicular to the line C_LC_R, see Fig. 1(c). One cannot expect the position of the ROI to vary greatly between the two successive frames.

Hence, the position of the current C_L and C_R in the current frame can be considered as the starting points of the region-growing in the next frame.



(a)



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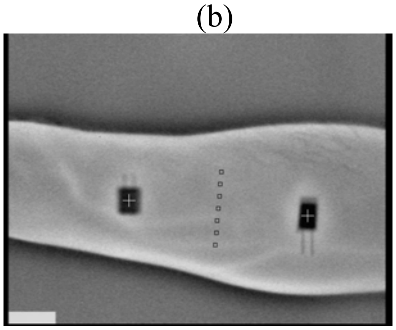


(c)

Fig. 1 Location of region of interest (a) original image (b) segmentation (c) location of the markers and the region of interest

From the second to the fifth frames of three series of images are shown in Fig. 2. We can see the markers, consequently the ROIs, can be located reliably frame by frame. This guarantees the precision of temperature statistics over the series of images.

The moving averaging is adopted. E.g. averaging of frame 1 to frame 5 is considered as new frame 1, averaging of frame 2 to frame 6 is considered as new frame 2, etc., see Fig. 3. The average temperatures of the region of interest were displayed in Fig. 4 that demonstrate the temperature changes before, during and after the exercise. The experimental results on the eight normal volunteers are found to be consistent in our lab. E.g. the results of the person No.1 and No.3 are shown in Fig. 4 (a) and 4(b) respectively. It can be seen that the temperature incremented immediately once the subject starts the exercise (i.e. to lift the dumbbell, from frame 1 to frame 300), however, decreased during the exercise (frame 301-900). It increased once the subject stop the exercise and then decreased slowly (frame 901-3000). The smooth effect due to the average can be seen clearly in Fig. 4, where the results includes one frame (blue), averaging of three frames (pink) and five frames (yellow) respectively.

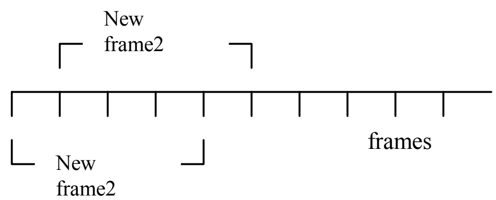


Fig. 3 Reducing noise by averaging frames

FFT analysis was done on the series of the average temperature so that the underlying frequencies of skin modulation range in the period can be found. The result is shown in Fig. 5. Each frequencies index unit in Fig. 5 corresponds to about 50 mHz. We can see in this figure that the underlying frequencies of skin modulation range from a few mHz to several Hz.

III. Conclusion

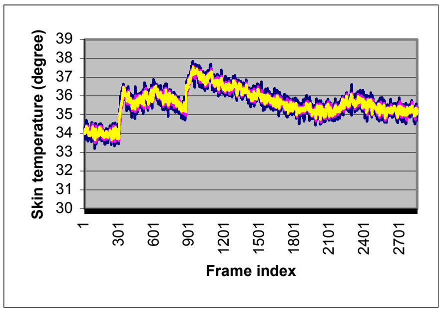
It could be possible to provide diagnosis information using the deference between health subjects and patients to specific exercises. Hence, it is important that pathological studies are complemented by investigations of healthy subjects.

In this paper, we implemented the skin temperature before, during and after a specific exercise we designed. The resolution of the skin temperature is improved. The underlying frequencies of skin modulation were found to range from a few mHz to several Hz in the exercise.

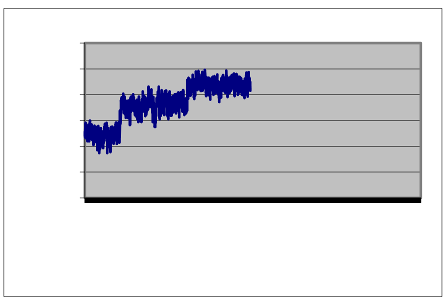
Although we have done the experiments on some normal subjects, however we acknowledge that the experiments on more normal subjects are

needed in order to verify the results obtained in this paper. Furthermore, investigations on the difference between patients and health subjects respect to the exercise are more important in the future work, because this will provide useful diagnosis cue.

A standard thermographic image not only has less contrast than a photographic image, it also has far more noise. The methods that reduce the spurious noise more efficiently than the frame averaging method will be investigated in the future work.



(a)



(b)

Fig. 4 Temperatures of ROI before (frame 1- frame 300), during (frame 301- frame 900), and after (frame 901- frame 2500) exercise. (a) Person No.1; (b) Person No. 3.

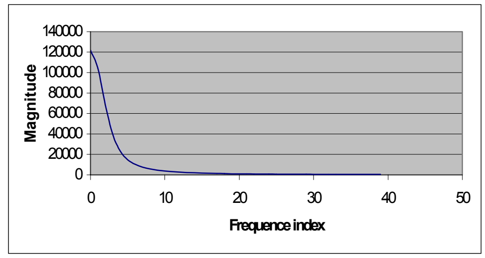


Fig. 5 FFT analysis of the average temperature of the person No.1

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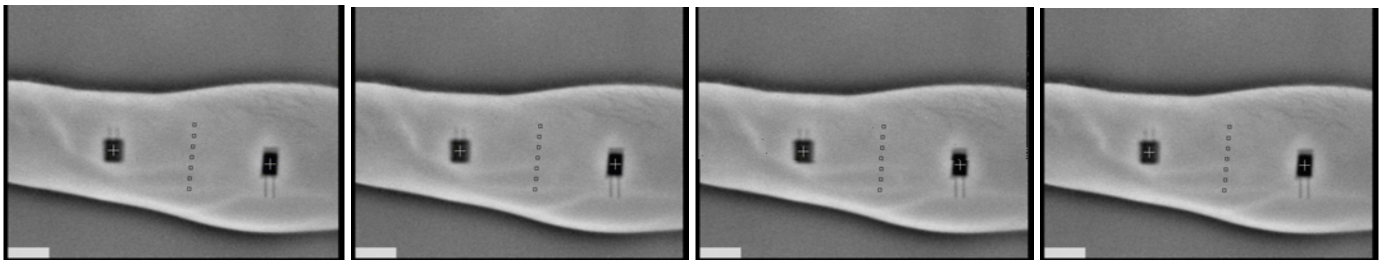
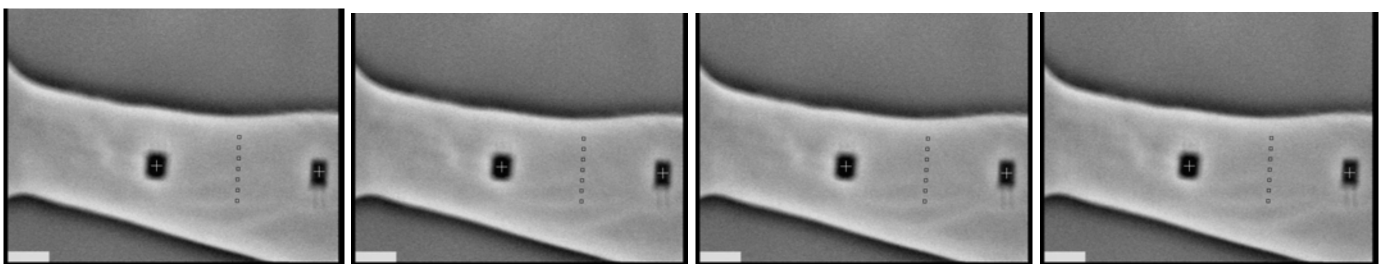


(a)



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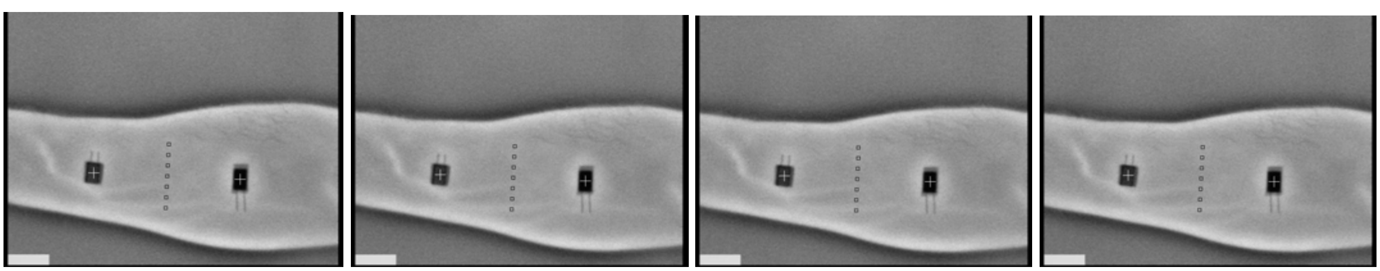

(c)

Fig. 2 Location of ROIs for a series of images (a) before exercise (b) during exercise (c) after exercise